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Switching current of the domains ensemble with serrated charged walls

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We derived an analytical formula describing switching current induced by the ensemble of cone-like domains growing within plane capacitor. In order to make our considerations descriptive and lucid, we restrict ourselves to the simplest case of simultaneous arising of the domains at t=0. The solution of the announced problem includes several steps:

(1) **The solution of corresponding electrostatic problem** of the charge induced at the plates of shorted plane capacitor by the dipole placed within it. The solution of this problem follows well-known classical approach [1]. The consideration is carried out for the case of isotropic dielectric permittivity $\varepsilon = 1$. This is done for simplification of the main formulas and for illustrative demonstration of obtained results. The generalization for the case of anisotropic dielectric permittivity is straightforward and will be presented elsewhere. Using obtained solution, the time dependence of the switching current induced by the growing isolated cone-shaped domain is derived. According to setting of an electrostatic problem, the effect of external screening is automatically accounted for, while retarded bulk screening effects for simplicity are totally ignored. The possibility of accounting for bulk screening and its effect upon polarization reversal current are discussed.

(2) **The solution of the stochastic problem** of the average surface of overlapping domains ensemble necessitates modification of Kolmogorov-Mehl-Johnson-Avrami approach. This modification has been carried out following [2,3], where it has been formulated mathematically by introducing the Boolean valued representative functions $u(\boldsymbol{r}, \boldsymbol{R_i}, t)$, with the properties: $u(\boldsymbol{r}, \boldsymbol{R_i}, t) = 1$ if $\boldsymbol{r} \in$ domain volume and zero otherwise. Here $\boldsymbol{R_i}$ is so called representative point –center of nucleation. It is shown that for simultaneous nucleation the solution of statistical averaging over randomly distributed nucleation centers, using representative functions, is based on the formula from the theory of sets: the union of two sets A and B is equal to $A \cup B = A + B - A \cap B$. Combining derived expression for average surface of cone-like domains ensemble with the results of electrostatic problem we arrive to the following formula describing time dependence of the charge induced at the capacitor plates:

$$Q(t) = -2P_S CH(t) \int_0^1 d\alpha (1 - \exp(-\alpha^2 \rho \pi R(t)^2),$$

where *R(t)* – radius of cone base, *H(t)* – cone height, ρ – density of nucleation centers, *C* – capacitance.

Proposed stochastic approach can be generalized for the description of polarization reversal current of the ensembles comprised of the domains of various shapes. Moreover, the proposed approach to the formulated stochastic problem can be of interest for the description of surface confined reactions.

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